CARBON ISOTOPIC COMPOSITION OF GRAPHITE GRAINS IN THE EL TACO IAB IRON METEORITE. J. Zipfel[1], I. D. Hutcheon[2] and K. Marti[1]. [1]Department of Chemistry, University of California San Diego, 9500 Gilman Drive, La Jolla CA 92093-0317, jzipfel@ucsd.edu. [2]Isotope Sciences Division, L-231, Lawrence Livermore National Laboratory, Livermore CA 94551.

Carbon isotopes have been analyzed in individual graphite grains of the El Taco iron meteorite. Graphite is present in four distinct petrographic associations and a total of 28 grains has been analyzed from all areas. The C isotopic composition varies from $\delta^{13}C$ = +4 to -29 ‰ and exhibits well-defined correlations with graphite morphology. The El Taco graphites contain much less N with CN^-/C^- ratios of 0.0027 to 0.005 than graphites from Acapulco or unequlibrated ordinary chondrites. Graphite appears to retain an isotopic record of precursor materials despite high peak temperatures and may be an important tracer of early solar system proceses.

In an ongoing study of the C and N isotopic record in primitive achondrites we studied in detail the El Taco IAB iron meteorite. We demonstrated N isotopic disequilibrium among coexisting mineral phases (metal $\delta^{15}N$ = -68‰, silicates $\delta^{15}N$ = +15‰) and widely variable $\delta^{15}N$-values within graphite separates (-50‰ < $\delta^{15}N$ <-22‰) [1]. Graphite and metal are the major carriers of N in El Taco with concentrations in the ppm range. Graphite separates from petrographically distinct associations within El Taco revealed several N-isotope signatures, indicating that the isotopic composition of individual graphites is probably distinct. Only a hand-picked graphite separate from the interface between matrix metal and inclusion silicates revealed a homogeneous N component with $\delta^{15}N$ = -35‰.

A similar study previously performed on the Acapulco meteorite revealed metal as the major N carrier and significant isotopic disequilibrium between metal (-142‰ < $\delta^{15}N$ <-35‰) and silicate (0‰ < $\delta^{15}N$ < +14‰) [2]. The N release of one particular metal separate indicated the presence of an isotopically heavier but combustible phase. A SIMS study of C and N isotopes in small graphite grains of distinct morphologies intergrown with metal revealed large variations in C-isotope composition, $\delta^{13}C$ = -34 to +14‰, accompanied by a diverse array of N-isotope compositions ($\delta^{15}N$ = -154 to -67‰) [3, 4, 5]. The origin of these isotope heterogeneities is not well understood but the variation in both $\delta^{13}C$ and $\delta^{15}N$ suggests a high retentivity of graphite for C- and N-isotope signatures, particularly since Acapulco was partially melted and recrystallized at temperatures exceeding 1000°C.

Based on results revealing isotopically distinct graphite separates in El Taco, we initiated SIMS *in situ* measurements of N and C isotope abundances in individual graphites. Our 40 g sample of El Taco contained three silicate inclusions embedded in matrix metal; mineral separates and a polished section were prepared. The section comprises the contact of the matrix metal with the inclusions and contains graphite in four petrographically distinct associations: (1) broad graphite layers up to 200 µm in width along the interface of silicate inclusions and the matrix metal; (2) individual cliftonitic and spherulitic graphites within the matrix metal only a few tens of micrometers apart from the silicate-metal interface; (3) small graphite rims around metal and silicate grains within the silicate inclusions; and (4) long graphite veins up to 300 µm wide extending from the matrix metal, crosscutting the silicate inclusions. A total of 28 grains from the four distinct associations were individually analyzed with the LLNL IMS-3f ion microprobe at a mass resolving power of ~6500. The $^{12}C/^{13}C$ ratios were standardized against USGS-24 graphite, $\delta^{13}C$ = -15.9 ± 0.25‰, and a terrestrial SiC, $\delta^{13}C$ = -26.08 ± 0.28‰ [6]. Results for the El Taco graphites reveal a diversity of C isotope abundances with $\delta^{13}C$ values ranging from + 4.0 to -29 ‰. Morphologically distinct graphites show well resolved differences in C-isotope composition. The long graphite veins (association #4) exhibit the largest ^{13}C depletion ($\delta^{13}C$ = -19.4 ± 3.7‰; the $\delta^{13}C$ values represent the average for graphites of a specific morphology), while the small graphite rims (association #3) are relatively enriched in ^{13}C, $\delta^{13}C$ = -1.1 ± 5.4‰). Graphites from the metal-silicate interface (association #1) have intermediate compositions, $\delta^{13}C$ = -10.4 ± 6.3‰, while the cliftonitic and spherulitic graphites (association #2) contain isotopically light C, $\delta^{13}C$ = -18.3 ± 7.0‰, similar to the veins cross-cutting the inclusions (#4)

Nitrogen concentrations in most El Taco graphites are very low; $^{12}C^{14}N^-/^{12}C^-$ ratios generally range from 0.0027 to 0.005 and only two grains had high CN^-/C^- ratios of 0.01 and 0.0073, respectively. No correlation exists between the C isotopic composition and the CN^-/C^- ratio. Based on relative sensitivity factors from terrestrial diamonds, we estimate N concentrations in the El Taco graphites of ~ 100 to 200 ppm. The CN^-/C^- ratios (N abundances) in the El Taco graphites is much lower than observed in any other graphites. In Acapulco CN^-/C^- ratios vary from 0.006 to 0.035 [3, 4, 5], while even higher values are reported in the unequilibrated chondrites Kainsaz (CO3) and Bishunpur (L3) (CN^-/C^- ratios of 0.005 to 0.108) and in presolar graphites from Murchison (CM2) (CN^-/C^- ratios of 0.01 to >1) [7,8]. The low N concentrations precluded simultaneous analysis of C and N isotope abundances but N-isotope measurements on these same El Taco graphites are underway.

The new results reported here demonstrate that the isotopic composition of C in El Taco graphites is not uniform and comprises a similar range as that found in Acapulco graphites. Equilibrium was not achieved among graphites from the distinct associations, giving rise to a compositional range of graphites much wider than anticipated from earlier studies. Deines and Wickman [9, 10] reported C isotope compositions ranging from $\delta^{13}C$ = -3.94 to -7.14‰ for four bulk samples from distinct silicate inclusions in El Taco; these values are assumed to reflect the isotopic composition of the graphite in these inclusions. Based on the compositional heterogeneity revealed in this SIMS study their results may reflect a mixture of carbon from graphites from the interface and those associated with silicates.

We conclude there are at least two distinct C reservoirs in the El Taco meteorite, isotopically light C ($\delta^{13}C$ ~ -30‰) associated with the matrix metal and heavy C ($\delta^{13}C$ ~ +5‰) associated with the silicate inclusions. This implies that not all graphites are exsolved from the metal. The intermediate composition of the graphites along the metal-silicate interface may reflect a mixture of both components. Graphite in the veins, crosscutting the silicate inclusions, must then be associated with the matrix metal and could be graphite mobilized during brecciation of the silicates. In order to test this hypothesis and better define the number of distinct isotopic reservoirs the signatures of N components are essential. If graphite is resistant to isotopic equilibration at high temperatures and preserves the composition of precursor materials, it may provide impotant clues to the nature of the original isotopic sources and to their method of incorporation into primitive achondrites.

References: [1] Zipfel J. et al. (1996) LPSC XXVII, 1501-1502. [2] Kim Y. et al. (1992) LPSC XXIII, 691-692. [3] El Goresy A. et al. (1994) LPSC XXV, 347-348. [4] El Goresy A. et al., (1995) Nature 373, 496-499. [5] El Goresy A. et al., (1995) LPSC XXVI, 367-368. [6] Mathez E. A. et al. (1995) GCA 59, 781-791. [7] Mostefaoui S. (1996) Meteoritics, A93. [8] Anders E. and Zinner E.K. (1993) Meteoritics 48, 490-514. [9] Deines P. and F. E. Wickman (1973) GCA 37, 1295-1319. [10] Deines P. and Wickman F.E.(1975) GCA 39, 547-557. Work performed under the auspices of the DOE by LLNL under contract W-7405-Eng-48.